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Total Network Data System:

National Network Management

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During periods of network stress, network management (real-time monitoring and control of the network) assures optimum call-carrying capacity. To assure timely reactions to network overloads and failures, the national Network Operations Center coordinates the activities of a set of network management operations centers. Supporting the Network Operations Center, the Network Operationa Center System collects data for major network elements and, within minutes, provides a national overview of exceptional conditions.

I. INTRODUCTION

Real-time monitoring and control of the network through a coordinated set of network management operations centers assures optimum call-carrying capacity during periods of stress caused by overloads and failures. Switching systems are controlled and monitored in detail in specific geographical areas at the 27 Network Management Centers (NMCs) that blanket the country. Regional Operations Centers (ROCs) coordinate NMC activities within each of the ten switching regions, and monitor and control the regional switching and signaling systems. To coordinate and manage the activities of the NMCs, the ROCs, and the two Canadian regional management centers, the na-

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tional Network Operations Center (NOC) at AT&T Long Lines' headquarters was placed in operation in 1977.[1]

The Network Operations Center System (NOCS), a one-of-a-kind system, supports the NOC. Twenty-four hours a day, seven days a week, NOCS collects data for the major elements of the telecommunications network, thousands of trunk groups, and hundreds of switching systems. It then checks these data for exceptional conditions, and displays information for these conditions within minutes of the occurrence. This national overview allows personnel at the NOC to coordinate appropriate reactions to national network situations, assuring uniformity of control.

The preceding paper in this issue of the *Journal*[2] explains the reasons for network management of the telecommunications network and describes the system that provides area and regional support for this function. In this paper, we describe the functions of the NOC, its support system, NOCS, and network management coordination for the North American telecommunications network.

II. NETWORK MANAGEMENT COORDINATION

2.1 *The network management operations structure*

As described in the preceding paper in this issue,[2] network management centers are organized in a three-level hierarchy. The national NOC is at the top level of this hierarchy and is supported by NOCS. Personnel at the NOC have ultimate responsibility for coordinating network management activities for situations that transcend regional boundaries. By assuring that actions taken optimize the use of network facilities, they protect areas hit by disasters and extraordinary calling volumes, coordinate the use of idle capacity when failures cut the capacity of normal routes, and assure consistent, compatible control application and removal.

While the NMC/ROC structure covers the entire domestic network, this center structure does not extend overseas. Most of the information about overseas destinations comes from data collected at the international gateway switching systems. Because no more than one gateway switching system is covered by any one NMC, the NOC plays a more direct role for overseas network management. Data from all gateways come together at the NOC. Thus, personnel at the NOC are in a unique position to see how calls from the domestic network as a whole are completing to overseas points. Because of this, NOC personnel take a more direct role in coordinating management activities at the international gateways and in working with overseas partners to assure consistency in methods and procedures.

2.2 *Network management methods*

In addition to monitoring the network and coordinating management activities in real time, the NOC is responsible for establishing a unified network management methodology. NOC personnel work with AT&T and Bell Laboratories to determine future directions and capabilities for network management. Guidelines for the selection of automatic control responses and for manual control strategies are sent to the ROCs and forwarded to the NMCs. The NOC organizes preplanning for anticipated problems and post-event analysis and critiques. Finally, the NOC is responsible for training network managers by arranging on-site rotational assignments, administering a training school, and issuing newsletters covering recent developments affecting network management.

Putting the responsibility for network management methods at the NOC assures a consistent, unified application of network management techniques throughout the domestic telecommunications network.

III. THE TELECOMMUNICATIONS NETWORK

The telecommunications network for which the NOC personnel are responsible comprises three distinct but highly interdependent networks.

First there is the top portion of the North American network hierarchy of toll switching systems and the trunk groups that interconnect them. This includes all ten United States regional (Class 1) switching systems and the two Canadian regional switching systems, about 70 sectional (Class 2) systems, 200 primary (Class 3) systems, and some toll (Class 4) systems. In total there are about 300 to 350 switching systems of interest to the NOC. The NOC does not monitor the local switching systems or their associated trunk groups.

The second network that the NOC personnel monitor is the overseas network, which comprises seven gateway switching systems through which all overseas traffic flows, trunk groups to several hundred overseas destinations, and a few trunk groups in the United States dedicated to overseas traffic between gateway systems. The seven gateway systems also serve as switching systems in the domestic network, where they range from Class 1 to Class 3 switching systems. The several hundred overseas trunk groups terminate in over one hundred foreign countries. There may be one or many trunk groups to any given country. Three different types of trunk groups within the United States are dedicated to overseas traffic. First, there are intergateway trunk groups reserved for overseas calls that overflow a particular gateway's trunk group to the destination country and must be routed to another gateway to use its trunk group to the desired

destination. Second, there are intergateway trunk groups that are used exclusively for incoming overseas calls that are merely transiting the U.S. to get to anotber overseas point. Third, there are trunk groups that connect the gateway systems to the overseas operations at the international operator centers.

The third network monitored by tbe NOC personnel is the Common Channel Interoffice Signaling (CCIS) network.[3] This high-speed, highly reliable signaling medium provides for fast call setup, efficient use and control of the network, and network features tbat require access to centralized databases. It is composed of several pairs of Signal Transfer Points (STPs) and tbousands of signaling links that are of interest to the NOC. The signaling links connect the STPs to each other, to the switching systems, and to centralized databases called network control points.

Collectively these three networks are composed of many elements. To receive data on all of them constantly at one location would be an enormous task. If it were done, only a small part of the data collected would be used most of the time. Because of these two facts, the NOCS does not receive data on all elements all the time. Rather, it receives data primarily on an exception basis: data are transmitted to the NOCS when a problem develops in an area. While there are a few items that are always reported, such as data on interregional final trunk groups and overseas trunk groups, data for most entities are rarely reported.

IV. OVERVIEW OF THE NETWORK OPERATIONS CENTER

The philosophy behind the Network Operations Center is exception alerting, followed by detailed reporting on the upper levels of the network. Because status information on all parts of the network would be much too voluminous to sort through manually, NOCS analyzes and displays information based on calculation results that exceed normal thresholds. Managers were alerted to these exceptional conditions in the network primarily by a wall display. This wall display, partially shown in Fig. 1, is visible from all operating positions. It is divided into network management and facility management sections. The display is functionally separated into two pieces; the right portion of the network management section displays information on the North American network, while status of overseas trunking is displayed on the left. The facility management portion of the wall display and the facility management function of the NOC are not discussed in this article.

The main part of the North American display is arranged in a matrix wherein each column represents data from one of the 12 switching regions. Conditions in any particular region affecting the

Fig. 1—NOC network management wall display.

rest of the network can be quickly deduced by scanning tbe appropriate column of the matrix. Similarly, conditions affecting a region can be detected by scaninng the appropriate matrix row. Thus, the network manager can quickly assess the location and scope of a network problem by viewing the domestic part of the wall display.

The main part of the international wall display is also laid out in a matrix fashion. The columns of this matrix represent the seven international gateways. The rows represent individual foreign countries. For backup and record-keeping purposes, wall display information is also printed on exception printers at the NOC.

For focus on individual exception conditions, CRT terminal displays provide resolution of data that triggers wall display exceptions. Other displays allow managers to analyze traffic patterns and aid in selecting and monitoring routes outside the normal routing chain when the normal in-chain routes cannot accommodate the traffic offered to them.

Analysis of troubles in the CCIS network is handled by an interactive, color graphics display, which provides information for both an overview and a detailed analysis of CCIS network problems.

V. NETWORK OPERATIONS CENTER SYSTEM

The primary need of the personnel at the NOC in carrying out their job is information—data telling them about problem conditions in the telecommunications network and helping them decide what, if anything, they can do to alleviate the problems. Making this information available quickly and in the most usable format possible is the task of the NOCS.

5.1 System architecture

Reference 2 describes how area and regional network management is supported by the Engineering and Administrative Data Acquisition System for Network Management (EADAS/NM). One function of these systems is data collection and screening for the NOCS. These systems collect data for all entities in the domestic network that are of interest to the NOC personnel. (The two Canadian regions are not monitored through EADAS/NM; data collection for those switching systems is provided by an E2 telemetry system.) The EADAS/NMs perform calculations on the data they collect and compare the results to thresholds establisbed by the NOC personnel. For those entities that have exceeded one or more thresholds and for those entities that the NOC personnel have scheduled, the calculation results are transmitted to the NOCS.

Working in conjunction with NOCS, the inter-EADAS/NM network collects data from the various EADAS/NMs. This network

consists of the Data Transfer Point (DTP) together with the set of links to the EADAS/NMs over which information is sent. The EADAS/NM links to the DTP operate asynchronously at 1800 baud. As we will note later, these links are used in both directions and do more than just transmit results of real-time data calculations to the NOCS.

Figure 2 shows the configuration of the multiprocessor NOCS with the DTP. Because of its important function in the network management environment, it is a duplicated system. It is possible to switch

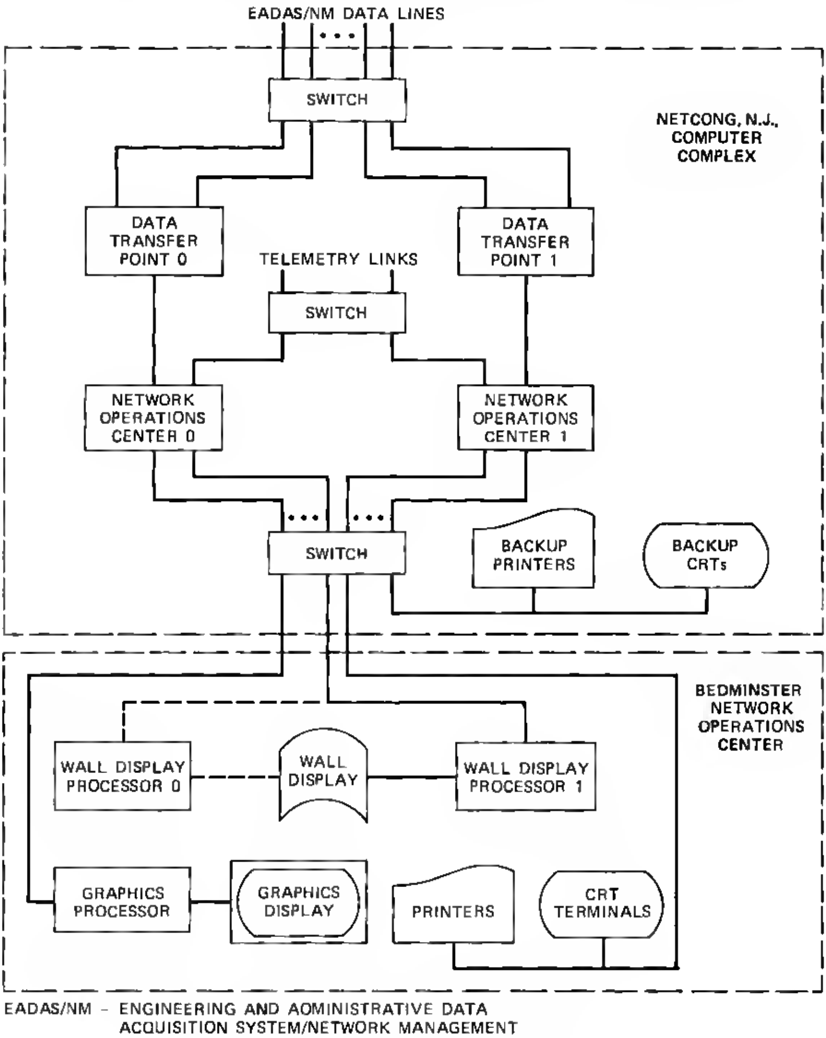

Fig. 2—System configuration for NOCS.

to the backup system within 15 minutes if a failure occurs on the active system. To achieve this, the backup system is always kept operational and is identical to the on-line system. Manual switches allow all EADAS/NM lines and all input/output (I/O) devices to be switched from one system to the other.

The primary computers in the system are not colocated with tbe primary display devices. As we stated earlier, the NOC is located in the Long Lines headquarters building in Bedminster, New Jersey, where the primary set of display devices and the small peripheral processors are located. The main computers, though, and the terminations of the EADAS/NM links are located about 25 miles away in Netcong, New Jersey. Also located at Netcong are a minimal set of backup display devices that can be used if a failure prevents the use of the facilities in Bedminster.

A simplex configuration of the systems would consist of the following elements:

1. The Data Transfer Point
2. The Network Operations Center System (NOCS) processor (labeled NOC in Fig. 2)
3. The Wall Display Processor (WDP) connected to the wall display
4. The Graphics Processor (GP) connected to the graphics display and the joystick
5. The Receive-Only Printers (ROPs)
6. CRT terminals.

Each DTP-NOC pair has a permanent high-capacity link joining the two processors. The WDPs are connected through the switch arrangement to a NOCS processor via a 4800-baud link. The wall display is 12 feet high, about 85 feet long, and uses luminescent, electromagnetically controlled indicators. These indicators are about one-inch square with black on one side and a reflective, highly visible color on the other side. Most of the wall display surface is actually taken up with labels. These identify the entities associated with the conditions represented by the indicators. The GP is also connected through a switch to a NOCS processor via a 4800-baud link. The ROPs are 4800-baud printers. The system supports botb 1200-baud and 4800-baud CRTs. The telemetry links shown in Fig. 2 collect data from the two Canadian regions.

5.2 DTP functions

Although the DTP performs several functions in the network management support system environment, its primary function is transferring data among the links that terminate on it. These links connect with the EADAS/NMs and the NOCS processor. Address information received in each message enables the DTP to determine on which link

or links the message is to be transmitted. Sometimes the message cannot be routed because of insufficient address information. In these instances the DTP must retrieve additional address information from its database before it can transmit the message to its proper destination(s). Keeping this additional address information in the DTP database eliminates the need to maintain it at all the EADAS/NMs.

In Section 5.1 we stated that the EADAS/NMs determine what data the NOC personnel want and then transmit tbat data to the NOCS. This information arrives at the DTP addressed to the NOCS, which is where the DTP routes it. In addition to this type of message the DTP also receives messages from the NOCS processor addressed to one or more EADAS/NMs. Tbese messages supply information such as thresholds to be used to determine what data to send to the NOC. The DTP also receives messages from EADAS/NMs addressed to other EADAS/NMs.

The basic data update interval used by the network management centers and the NOC is five minutes. Althougb some events are reported as they occur or soon thereafter, the bulk of the network management data consists of counters scored locally by tbe switching systems or STPs. These are read and zeroed once every five minutes. The timing of these five-minute intervals is another function that the DTP performs. When a period begins, the DTP sends a message to the NOCS processor and to all the EADAS/NMs. As soon after the beginning of the period as possible, the EADAS/NMs start collecting data from the entities for which they are responsible, performing the calculations on these data, and sending the exceptions and scheduled data to the DTP. The DTP receives this five-minute data and passes it on to the NOCS processor until all the EADAS/NMs have reported that they have sent all their data. In the event tbat a cutoff time near the end of the five-minute interval is reacbed, the DTP stops the EADAS/NMs from further transmission and forwards tbe available data to the NOCS processor. When all EADAS/NMs have completed data transmission or the cutoff point is reached, the DTP sends a message to the NOCS and all EADAS/NMs to inform them that this period is over. Five-minute data for a period received by the DTP after the cutoff point is not passed on to the NOCS processor.

The DTP also monitors the inter-EADAS/NM links for problems and keeps its database up to date. If any of the links from the EADAS/NMs are having trouble, the DTP disconnects those, and then tries to reconnect them to clear the condition. The current status of all links is constantly available and can be accessed by the NOC personnel. The DTP receives all its database information automatically from the NOCS processor. Whenever the NOCS processor or the DTP is restarted, or the NOC personnel install new information in the NOCS

database that could affect the DTP, the NOCS processor updates the DTP database without any manual intervention.

5.3 Reference data

The NOCS must have a large amount of reference data to display information. This reference data reflects the characteristics of all the switching, trunking, and signaling entities discussed in Section III. The NOCS reference data must be consistent with the reference data used at the EADAS/NMs. To achieve this consistency, and to handle the many database changes that occur, NOCS derives a major portion of its reference data from reference data tramsmitted by the EADAS/NMs to the NOCS processor over the inter-EADAS/NM links. It generates the remainder from data that are input by the NOCS database administrator.

The reference data transmitted from the EADAS/NMs to the NOCS processor are in binary format. When these data are received, they are converted to an ASCII format and stored in the NOCS. The NOCS database administrator can then modify and augment this information as required before using it to create the active NOCS database. Some information that is needed in the NOCS database is not received from the EADAS/NMs and must be manually entered and updated at the NOCS. The NOCS database administrator has a set of commmands to create, modify, examine, and audit additional reference information. The creation and installation of the active database from the combined EADAS/NM and locally supplied reference information are also under the control of the NOCS database administrator.

In addition to the reference data sent to the NOCS from the EADAS/NMs, there is also reference data sent from the NOCS to the EADAS/NMs. These include such items as thresholds to be used by the EADAS/NMs and a common set of location (switching system and STP) identifiers. To ensure that all EADAS/NMs are using the same version of these tables, each version has a unique identifier sent along with it. Whenever an EADAS/NM is reconnected to the DTP, it sends the NOCS a list of its current table identifiers. If they are not the correct set, the NOCS sends the EADAS/NM the proper tables automatically.

5.4 Real-time data

The types of real-time data that the NOCS receives from the EADAS/NMs include:

1. Five-minute data calculation results
2. Switching system and STP status indicators (hereafter referred to as machine status indicators)
3. Control activations and deactivations.

We discussed the five-minute data calculations in Section 5.1. The EADAS/NMs collect data, perform calculations on the data, compare the results to NOCS established thresholds, and transmit exceptions and scheduled data to the NOCS. The EADAS/NMs collect data on trunk groups, signaling links, switching systems, STPs, and destination codes. These raw data are used by the EADAS/NMs to calculate rates and percentages, which can then be compared to thresholds. Whenever it is determined that a calculation result exceeds its threshold, all the data for the entity concerned are sent to the NOCS.

The NOCS stores all the five-minute data calculation results that it receives in an interval for twenty minutes. Therefore, at any time network managers can retrieve the data for the four most recent five-minute time periods. When data for a new five-minute period are available, exceptions are immediately displayed and automatically recorded for the network managers. We discuss this further in Section 5.5.

NOCS uses the machine status indicators, received as often as every 30 seconds, to notify the NOC personnel of any significant switching system or STP problem as quickly as possible. The events that are reported include congestion and failure conditions measured at switching systems and STPs. Whenever new machine status information arrives, NOCS immediately displays it to the network manager. In addition, a history of all machine status changes is kept and is available to the network managers (see Section 5.5).

The third type of real-time data that NOCS receives is control activations and removals. NOCS receives information on code controls and trunk group cancel, skip, trunk reservation, and reroute controls. At the time that any of these controls are applied to or removed from a NOC interest trunk group, the NOCS is informed. Furthermore, the NOCS control audit capability permits it to request an update of all the controls that are active in all the switching systems monitored by an EADAS/NM.

5.5 Data display

Sections IV and 5.1 described briefly the functional characteristics of the NOCS I/O devices. This section describes how these devices provide an interface to the user.

5.5.1 The wall display

The primary objective of the wall display is to alert the network managers to problems in the network. In general it is not used to determine exactly what a problem is or how severe it is; this is done by other I/O devices available on the system. The indicators on the wall display are used to inform the NOC personnel that some calcu-

lation result has exceeded its threshold, some system condition has activated a machine status indicator, or some control has been invoked. About 30 percent of the wall display on the left is used for overseas items, about 40 percent in the middle is used for domestic conditions, and the remaining portion on the right is used for a display of transmission facilities. This right portion is not controlled by the NOCS and is not discussed in this article.

The domestic section has four general areas, as shown in Fig. 3. Area 1 is the largest portion. Its 12×12 matrix display of intraregional and interregional trunking conditions was described in Section IV. Each column has the regional center name at the top and tbe names of all the regional and sectional centers below it. To the left of each switching system name are four indicators that reflect conditions from the regional center listed at the top to that particular system. Area 2 also lists all the regional and sectional centers. To the left of the names this time are seven indicators that reflect code controls or trunk group controls activated at the named systems. To the right of these names are six (for sectional centers) or seven (for regional centers) more indicators showing the machine status indicators. Area 3 contains more specific information on which machine status indicators are active, as well as some miscellaneous items about tbe NOCS, threshold tables in use, and other conditions. Area 4 is similar to Area 1 in that there is a column for each of the twelve regions. Each column shows the status of the STPs in the region and the signaling links that emanate from them.

The overseas portion of the wall display is shown in Fig. 4. The layout in this portion is straightforward; all the countries that have trunk groups are listed in three columns. Each country also has the names of its gateway switching systems listed. To the left of the country names two items are shown: (1) a label listing tbe International Operator Center(s) that serves the country, and (2) indicators displaying code controls in effect. To the right of the country names

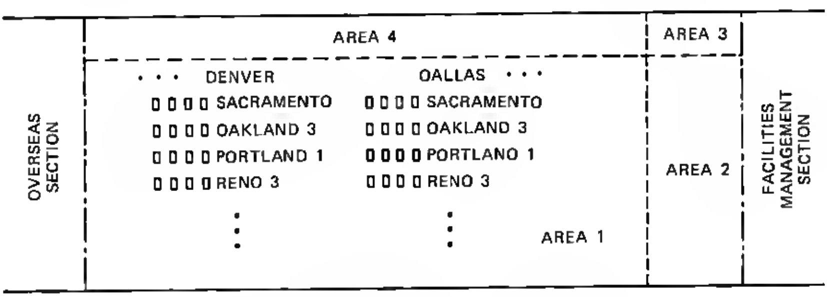

Fig. 3—Domestic section of the wall display.

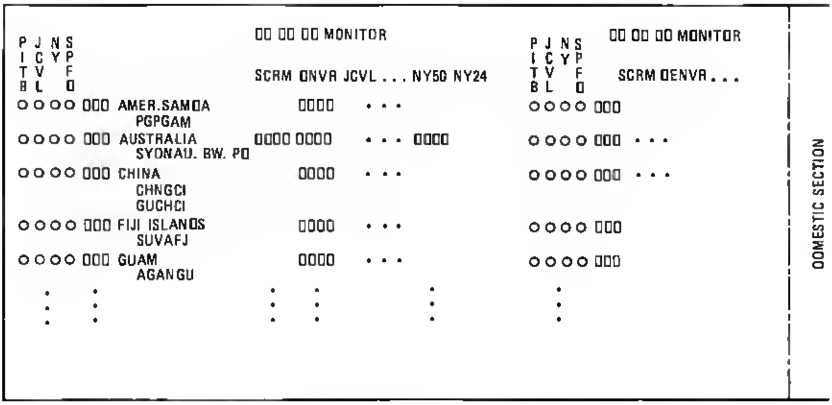

Fig. 4—Overseas section of the wall display.

are seven columns for the seven U.S. gateway switching systems. If a gateway serves a country, there are four indicators that show conditions to that country.

5.5.2 *The CRTs*

The CRTs are the primary tools that enable network managers to retrieve switching and trunking information from NOCS. Once alerted to a problem by the wall display, network managers analyze details of the problem using the CRTs. Since the network managers at the NOC have to obtain information from the system as fast as possible, a series of fixed format displays have been developed for use on the CRTs. They provide quick access to almost all the data in the system with a minimum of input. These displays or "pages" are divided into the following categories:

1. Analysis pages, for analyzing traffic data patterns
2. Exception pages, for resolution of data-triggering exception indicators on the wall display
3. Input pages, for some of the database modifications.

The pages provide access to data for the four most recent five-minute periods, current machine status indicators, and current controls. A page consists of up to 68 lines, 80 characters in length. It contains fixed information, known as "background" and variable input and output areas, referred to as "windows." Input windows enable network managers to select parameters quickly by entering a single character designate (+), or a short string of characters, such as the first few characters of a Common Language Location Identifier. After designating the appropriate input parameters or using the default values where appropriate, the network manager depresses the SEND

key. The system then responds by filling in the output windows with the desired information.

Of the eleven analysis pages in the system, seven are for analyzing domestic trunk group conditions, such as reroute controls in effect or interregional trunk group congestion. The other four are for looking at overseas trunking conditions, such as the traffic from a gateway to a country. The 13 exception pages provide data for machine exceptions, domestic and overseas trunk group exceptions, and code-related completion problems.

Figure 5 is an example of an analysis page. This page is for viewing trunk groups from one geographical area to another. In the area at the top and along the left edge, the network manager enters selection parameters in input windows. The remainder of the page is the display area (output windows) for the trunk groups that meet all the input selection criteria. This area identifies the trunk groups by the Common Language Location Identifiers of the switching systems at each end, and data shows calculation results and conditions affecting the trunk group.

In addition to providing access to current data, status, and controls, the CRTs serve other purposes. The NOCS maintains a history of machine status indicators. Using a system command entered on any of the CRTs, network managers can obtain specific subsets of this file tailored to their current interest. A report may cover from 30 minutes to several days of data, and may specify a single machine or all machines, as well as one or more specific status indicators. The data in the report can be ordered by time or by machine.

```
AN85 OUTGOING NETWORKS                                       FROM AREA ( ) [                    ]
MF( )  CCIS( )  ALL(s)        FNL( )  HU( )  ALL(s)           TO  AREA ( ) [                    ]
-------------------------------------------------------------------------------------------------
     SC  SN  DN  DL  ST  NR  RC  PI  WA  WH  MT  RE  FR  ALL   R   S   PT  ALL           TIME
FM  ( ) ( ) ( ) (s) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( )   (s) ( ) ( ) ( )   0-5   0-15  0-20  5-20
TO  ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) ( ) (s)   (s) (s) ( ) ( )   (s)   ( )   ( )   ( )
-------------------------------------------------------------------------------------------------
 OR  ( )    | ACH >  5 and %OCC <  75                             %          %
AND  (s)    | FROM OFFICE          TO OFFICE               EQ2W OFL ACH CCH OCC TBIT CTRL % M
            | DLLS TX TL 34T( ) JCVL  FL CL 03T N2H   60    0   9   9  65 ---A RRT  50*
XCPT  ( )   | DLLS TX TL 34T( ) ALBQ  NM MA 02T N2H  120    0   5   5  72 ----
%OF[      ] | DLLS TX TL 34T( ) BLNG  MT MA 02T N2H   12    0   5   5  67 ----
ACH[      ] | DLLS TX TL 34T( ) DNVR  CO MA 01T N2H  120    0   7   7  69 ---- SKIP 75-
CCH[      ] | DLLS TX TL 34T( ) PHNX  AZ MA 01T N2H   72    0   9   9  75 ----
%OC[      ] | DLLS TX TL 34T( ) SLKC  UT MA 01T N2H   48    0  11  11  75 ----
            | DLLS TX TL 34T( ) BLTN  IN 01 04T N2H   23    0   7   7  51 ---- CANT 75-
TBIT ( )    | DLLS TX TL 34T( ) CHCG  IL CL 46T N2H  108    0   6   6  75 ----
   [      ] | DLLS TX TL 34T( ) DESM  IA DT 04T N2H   36    3  10  10  75 ----
            | DLLS TX TL 34T( ) FARG  ND BC 03T N2H   24    0   6   6  60 ----
CTRL ( )    | DLLS TX TL 34T( ) GDRP  MI BL 40T N2H   36    0  15  15  36 ----
   [      ] | DLLS TX TL 34T( ) MPLS  MN DT 04T N2H   84    0   9   9  70 ----
-------------------------------------------------------------------------------------------------
PART [ 1 ] OF 4   DATA FOR 11:35-11:40                             TRANSFER TO SINGLE-TG ( )
SEPT 1 82  11:47:46 NWT      PRINT ( )                 DIRECTORY[    ]        PAGE[    ]
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Fig. 5—Example of an analysis page.

A large set of system commands is available to administer and monitor the NOCS and its database. These commands are also entered on the CRTs and can be directed to either the NOCS processor or the DTP. The DTP commands permit such functions as the attaching and detaching of EADAS/NMs; the starting and stopping of exception transmission from an EADAS/NM; and the printing of DTP data tables, inter-EADAS/NM network status, and various other network statistics. The NOCS processor commands permit such functions as initializing and testing the wall display and graphics processors, administering the database (as discussed in Section 5.3), auditing EADAS/NMs for current status indicators and controls, and controlling the playback function (to be described in Section 5.6).

5.5.3 The graphics displays

The graphics subsystem of the NOCS provides an interactive, color display that is used as both an alerting device and a detailed data source. It is interactive in that its fast update rate permits the user to receive near instantaneous response to information requests. It is capable of displaying 17 colors in 15 different shades and producing two- and three-dimensional shaded displays. This device permits adjustment of three input coordinates and the selection of items in the displays. Cursors on the monitor show the current values of the three coordinates.

The operating system is designed to support up to 15 functions, or collections of closely related displays. These can show information from the four latest five-minute data periods along with the current controls and machine status indicators. The operating system can also automatically update the current displays with new data when the NOCS processor indicates it is available. Currently, the functions available on the graphics system are:

1. CCIS monitoring
2. Domestic trunk group monitoring and analysis
3. A geographic editor.

Since the graphics system is a relatively recent addition to the system, this list of functions is expected to grow.

The CCIS display pictorially represents all the elements in the CCIS network, and color-coded symbols alert the network manager to exception conditions. The display shows the latest sample of five-minute data and current CCIS-related machine status indicators for the entire CCIS network. This display allows the network manager to determine the general nature of CCIS problems. At that point the network manager can request that particular link sets with exceptions be expanded and that labels and specific data calculation results be shown. The domestic trunk group display graphically represents the

switching and trunking entities to be monitored and color codes problems to allow the network managers to focus quickly on the worst problem areas or to determine the type of problem that exists. The geographic editor is used for database administration only.

5.5.4 The printers

The receive-only printers on tbe NOCS are used as exception printers, as monitor subsystem printers, and for database work. The exception printers exist to maintain a permanent record of all domestic and overseas exceptions that are reported by the EADAS/NMs. Trunk group, machine, and signaling link exceptions are recorded.

The monitor subsystem gives the network manager a printed chronological record of data for up to 150 trunk groups. The trunk groups for which print criteria are selected and set are listed on a separate printer called the monitor printer. Furthermore, the network manager can activate special indicators on the wall display or set off an audible alarm when a monitor system threshold is exceeded. These wall display indicators exist on a per-region basis on the domestic part of the wall display and on a per-gateway-system basis on the overseas part of the wall display.

5.6 Playback

The playback subsystem of NOCS allows the status of the switching network, as reported to the NOCS by EADAS/NM and the E2A telemetry interface of NOCS, to be recorded and later replayed on the system. The recording is done at any time on the active NOCS processor. All the data messages that come over the DTP-NOCS link and all the data that comes from the E2A telemetry are copied to a file on the disk. This file is large enough to hold more tban a day's worth of data at normal system load. There are two such files on the disk so when one is filled, the other can be activated. Either file can be copied to magnetic tape for later analysis if desired. The recording of incoming data in the playback system disk file does not affect normal operation of the NOCS. When the record mode is activated, all pertinent system information that will be required to replay the data is also recorded.

Previously recorded network data can be replayed at any time on the off-line NOCS processor. If the data to be replayed are not currently in a playback system disk file, they are read in from magnetic tape. Using the switches, the system administrator can connect any combination of I/O devices, i.e., wall display, CRTs, graphics, or printers, to the system running replay. These devices will then appear as though they are connected to a NOCS processor that is receiving live data. When the playback system is running in the replay mode, it

retrieves the data stored on the disk file and feeds it to the NOCS as if it had just come from the EADAS/NMs or the E2A telemetry. Several options are made available to the replay operator. Replay can be made to run the system at a "normal" speed or faster or slower than normal. It can also be made to start at a certain point in the file and to continue from there, or to read in one period of data and not advance.

5.7 NOCS software features

Both the DTP and NOCS processor run *UNIX** operating systems and all the application code in both systems is implemented in the C programming language.[4] This paper will not attempt to go into detail on the software architecture of the NOCS. Rather, a few salient points of the implementation will be discussed briefly because of the part that they play in making the NOCS a successful real-time operations support system.

DTP software takes the data from the EADAS/NM lines and "funnels" it into one data stream for internal processing. Most of the messages are destined for the NOCS processor, so the DTP "blocks" as many as possible of the short EADAS/NM messages together into larger messages for efficient transfer through the DTP and to the NOCS.

Figure 6 shows the primary subsystems in the NOCS processor. All data coming in from the DTP or the E2A and all data going out to the DTP must pass through the Message Processing System (MPS). The MPS sorts incoming data into two basic categories: reference data and real-time data. It passes the reference data on to the Reference Data Update System (RDUS) to be processed as discussed in Section 5.3 while the MPS enters the real-time data into the database as they arrive. These processes also make certain data items immediately available to other processes so that the network managers can be alerted as fast as possible to potential problems. When all the data for a five-minute period are in, the MPS notifies all interested subsystems.

A prominent part of the NOCS software is the Data Access System (DAS), which handles all interactions with the database. The DAS is a large set of subroutines that provide common, standard access to the real-time and active reference database files. This single point of access to the system database has many benefits; the two most prominent ones are:

1. Standardized, centrally maintained retrievals that can be used by a multitude of processes

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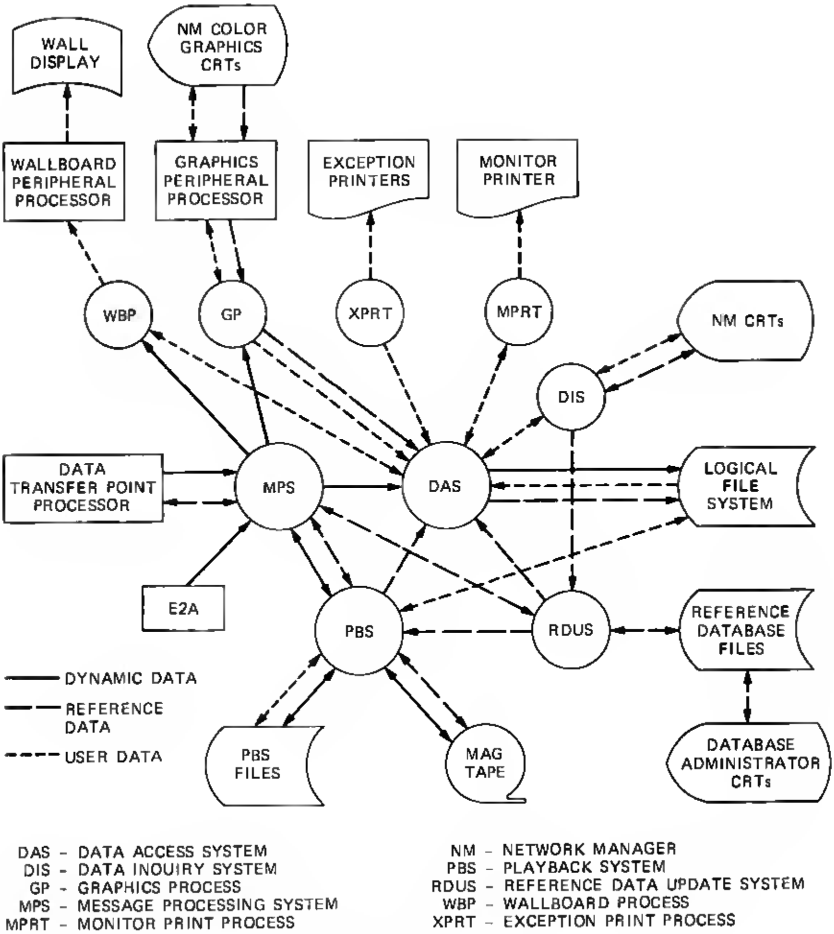

Fig. 6—Major NOCS software systems.

2. Control of the reading and writing of individual files by a multitude of processes.

In addition to these benefits, the DAS also provides relief on system disk I/O through a per-process cache buffering mechanism that allows frequently accessed disk sectors to be kept in core, thereby avoiding additional disk reads.

In the NOCS processor the real-time data and active reference database are not kept in the standard *UNIX* file system but rather are maintained in a special file system called the Logical File System (LFS). The LFS is implemented using the raw I/O facility in the *UNIX* operating system. It provides a fast excess file system that:

1. Isolates the applications programs from having to know the physical disk location of files.

2. Enables application programs to create, delete, read, write, switch, and copy logical files.

3. Contiguously stores LFS files. This results in reduced disk I/O transfer time.

4. Transfers LFS files directly between the disk and the application data area, thereby reducing system overhead on each disk transfer.

The portion of the grahics subsystem that resides in the GP (Graphics Processor) runs under a specially designed operating system. The system provides functions required by the applications processes that drive the graphics displays. Most of the code that resides in the GP is implemented in C language; the remainder, though, is implemented in assembly language or is microcoded. This non-C code exists only in the operating system and is used to achieve the speed required to produce the interactive displays.

VI. CONCLUDING REMARKS

The NOC, supported by NOCS, plays a key role in coordinating and managing the North American telecommunications network. Its role is evolving from coordination of different geographical areas of the MTS network toward coordination and management of different subnetworks and service capabilities of the telecommunications network. We discussed the North American message network, the CCIS network, and overseas trunking. Another function of the NOC, not yet supported by NOCS, is monitoring and control of System 800, as noted in Ref. 2. As the network evolves with topological changes, new approaches to common channel signaling, and new service capabilities, we expect coordination and management of new service capabilities and the interactions of different network components to become an increasingly important part of the NOC's job.

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